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U.S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN

637

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 25, 1915.

THE GRASSHOPPER PROBLEM AND ALFALFA CULTURE.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

SPECIES RESPONSIBLE FOR DEPREDATIONS.

While specimens of the species of grasshoppers actually engaged in devastating alfalfa fields have not always accompanied complaints of their ravages, it is nevertheless possible, taking the data secured by Government and State officials in connection with information from correspondents, accompanied by specimens of the insects actually committing these depredations, to fix the responsibility—largely at least—upon three species. One of these is known as the differential grasshopper (*Melanoplus differentialis* Thos., fig. 1), another as the two-striped grasshopper (*Melanoplus bivittatus* Say., fig. 2), and the third, *Melanoplus atlanis* Riley; the last being more or less migratory.

Other species of grasshoppers have probably at times been more or less involved, as it is rarely that material submitted with a complaint of damages does not include more than one species; on the other hand, species ravaging other crops on the same farm or ranch are often submitted under the supposition that they are like those seen at work in alfalfa. A notable case in point is that of the yellow-winged or pellucid grasshopper (*Camnula pellucida* Scudd.), which, while very destructive to grain and grass crops, is said to work but little injury to alfalfa. However, as all grasshoppers likely to become involved in this or similar depredations have much the same habits and all are probably susceptible to the same treatment, the question of species is not one to interest the farmer particularly, beyond the matter of his ability to determine for himself which one is the worst pest and to apply his measures of suppression more especially with reference thereto.

APPLICABILITY OF MEASURES HEREIN DESCRIBED TO CLOVER CROPS.

While this bulletin is primarily for the benefit of the alfalfa grower, the measures of suppression recommended may be applied in the

Note.—This bulletin describes the species of grasshoppers that work special injury to the alfalfa fields and suggests methods for their destruction. It will be of interest wherever alfalfa is threatened by an attack from these insects.

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clover fields of the eastern section of the country with equally good results. Indeed, the three species here discussed are at times destructively abundant in the red-clover fields of the East and Middle West, and the writer has there used the "hopperdozer" to advantage.

EARLY DEPREDATIONS.

With the rapid increase in the culture of alfalfa throughout the country there has come the problem of protecting this crop from attacks of several species of grasshoppers, or locusts. The reason for this state of affairs is not at all obscure, as in order to breed freely and in destructive numbers these grasshoppers require two conditions: First, an undisturbed soil for the protection of their eggs after these have been deposited; and, second, an early food supply for the young in spring. No other crop comes so near supplying these conditions to an ideal degree as does alfalfa.

FIG. 1.—Differential grasshopper (*Melanoplus differentialis*). Natural size. (After Riley.)

Thus it is that the farmer, especially in the West, has from the beginning of alfalfa culture been sorely beset by these pests, whose destructive hordes might even now be said to follow closely in the footprints of the reclamation engineer.

SERIOUSNESS OF INJURIES.

Hardly a season passes during which more or less serious outbreaks are not reported in different localities, and the aid of the Bureau of Entomology is frequently invoked in destroying these grasshoppers or otherwise lessening their ravages. Thus, during the year 1913, serious widespread injuries occurred in New Mexico, Kansas, Oklahoma, New Hampshire, and Vermont, with lesser outbreaks in Arizona, Texas, Mississippi, Wisconsin, Michigan, and Wyoming. It is in no wise likely that these numbers indicate more than a minor portion of the destructive outbreaks of these pests that actually occurred over this territory, and the seriousness of some of these outbreaks is indicated by the fact that as many as 12 complaints were received from a single locality. In fact, the probabilities are that, as the area of cultivation of alfalfa increases, the amount of injury inflicted by these insects will greatly increase in future unless measures are taken to control them.

DESCRIPTIONS OF THE TWO PRINCIPAL ALFALFA-AFFECTING SPECIES.

The differential grasshopper (fig. 1) is about 1½ inches long, its wings expand about 2½ inches, and it is of a general bright yellowish-green color. There is, however, a nearly black melanic form that does not seem to differ otherwise from the normal. The head and thorax are olive brown, and the front wings are of very much the same color, without other markings but with a brownish shade at the base; the hind wings are tinged with green; the hind thighs are bright yellow, especially below, with four black marks; the hind shanks are yellow, with black spines and a ring of the same color near the base.

FIG. 2.—Two-striped grasshopper (*Melanoplus bivittatus*). Natural size. (After Riley.)

The two-striped grasshopper (fig. 2) varies in color from a dull green to a dull brown, with a distinct yellow stripe extending on each side from the upper part of the eye to the end of the wing. The male is about 1¼ inches long and the female about one-fourth of an inch longer. This grasshopper may be so easily recognized from the accompanying figure that further description is unnecessary.

The young are very much like those of the Rocky Mountain grasshopper, or locust, shown in figure 3.

FIG. 3.—Rocky Mountain grasshopper or locust (*Melanoplus spretus*): *a*, *a*, Newly hatched larvæ; *b*, full-grown larva; *c*, pupa. Natural size. (After Riley.)

DISTRIBUTION OF THE TWO SPECIES.

Although both these grasshoppers seem to be generally distributed over the country, the differential grasshopper rarely becomes destructively abundant east of the Mississippi River. It is very decidedly so, and with great frequency, however, to the west of the Mississippi, while, though extending from Maine to California, the two-striped grasshopper is sometimes disastrously abundant, locally at least, as far east as Ohio. In the red-clover-growing sections of the country the two-striped species is probably very much the more destructive of the two, though even as far east as Indiana the differential grasshopper does considerable injury to fruit trees by gnawing the bark from the twigs.

LIFE HISTORIES AND HABITS.

The eggs are deposited in the ground in masses, inclosed in more or less kidney-shaped pods, in late summer and fall, after the manner shown in figure 4, which illustrates the oviposition of the Rocky Mountain grasshopper or locust. The females seem to prefer a moderately compact, rather damp but not wet soil which is rarely disturbed by the plow or other cultivating implement. It will thus be seen that the alfalfa fields throughout the irrigated sections constitute an ideal breeding ground. Winter is passed in the egg state, the young hatching in spring and reaching maturity in summer, and there is but one generation annually. Neither of the two species is migratory. Their flight is rather clumsy, and they do not remain long on the wing before alighting.

FIG. 4.—Rocky Mountain grasshopper or locust (*Melanoplus spretus*): *a*, *a*, *a*, Female in different positions, ovipositing; *b*, egg-pod extracted from ground, with the end broken open; *c*, a few eggs lying loose on the ground; *d* and *e* show the earth partially removed, to illustrate an egg mass already in place and one being placed; *f* shows where such a mass has been covered up. (After Riley.)

NATURAL ENEMIES.

Upward of 100 species of birds are known to feed to a greater or less extent upon grasshoppers, but probably the most useful in this direction are quails, prairie chickens, the sparrow hawk and Swainson hawk, the loggerhead shrike, all cuckoos, the cowbird, all blackbirds and meadowlarks, the catbird, and the red-headed woodpecker. That domestic fowls are especially fond of these insects goes without saying. Skunks are very fond of grasshoppers, and are esteemed by the Bureau of Biological Survey as the most useful of mammals; they therefore deserve protection rather than destruction by the farmer. Toads and probably some of the snakes add these insects to their bill of fare.

Of the insect enemies, the grasshopper mite is often found infesting grasshoppers in great numbers. It collects under the base of the wings, sometimes causing them to stand out from the body. While these mites probably destroy many grasshoppers, it is possible that their value to the farmer has been overestimated. There are several species of parasitic flies that frequently destroy immense numbers of these grasshoppers. Of these *Sarcophaga kellyi* Ald., *S. cimbicis* Towns.,

S. hunteri Hough, and *S. georgina* Wied. (fig. 5) sometimes sweep these locusts off in myriads. These flies deposit minute, elongate maggots on the surface of the bodies of the grasshoppers. The young maggots make their way directly into the body of their host, and as they grow and develop there they feed upon the living insect. When full grown the maggots go into the ground and within a brown case transform to flies. Quite recently Mr. E. O. G. Kelly, of the Bureau of Entomology, has discovered a species of Sarcophaga attacking grasshoppers in great numbers in the State of Kansas. This species deposits the tiny maggots upon the outstretched wings of the grasshopper when in flight, whence the maggots make their way into the soft integuments of the body. Mr. H. E. Smith observed the same species likewise depositing its larvæ on its victims while the latter were quietly clinging to vegetation. This species was found to be new to science, and has been described under the name of *Sarcophaga kellyi* by Dr. J. M. Aldrich.

FIG. 5.—*Sarcophaga georgina*, a parasitic fly that destroys grasshoppers. Much enlarged. (Author's illustration.)

While all of these natural enemies do much to hold the pests in check, there are two or three vegetable parasites that also kill off myriads of them, the dead bodies of the grasshoppers destroyed thereby often being conspicuous objects as they cling to the weeds and grass where death overtook them (see fig. 6). One of these fungous parasites is the same as that attacking the chinch bug, and is known to science as *Sporotrichum globuliferum*. A group of grasshoppers that have been killed by this fungus is shown in figure 7.

While it will be seen that there is no lack of natural enemies of these grasshoppers, and while all of them are of benefit to the farmer, they do not and never will afford absolute protection from the ravages of these pests in the alfalfa fields. The reason for this is plain. By growing a single plant over large areas the farmer produces an unnatural condition and offers unnatural advantages for the development of the enemies of this plant, the grasshoppers. It is really the number of plants that invites insect attack. So, also, it is the great number of grasshoppers congregated together in masses that invites attack from natural enemies, and it is only when this condi-

tion is present that these natural enemies become sufficiently abundant to offer the farmer prompt and effective relief. In other words, the natural enemies, however much restraining force they may present, are always too far behind wholly to prevent occasional outbreaks of these grasshoppers. The farmer, having undertaken the cultivation of alfalfa in large areas under conditions preeminently favorable for

FIG. 6.—A view of grasshoppers dead and dying from fungous disease. Natural size. (From Howard.)

the development of grasshoppers, must now throw some restraining element into the other side of the scales in order to preserve the balance. It thus comes about that artificial repressive measures must be put into play in order to counteract, as it were, the effect on nature of an overabundance of alfalfa plants—a vastly greater number than would be produced under natural conditions. And this brings us to a consideration of preventive and repressive measures.

PREVENTIVE AND REMEDIAL MEASURES.

Preventive measures, as here restricted, apply to a period antedating the hatching of the young; while remedial measures are such as deal with the insects after hatching and with methods of destroying them.

While many modes of procedure have been advocated, tending to ward off impending attacks, and perhaps even a greater number of devices constructed and mixtures compounded for the destruction of grasshoppers, we will here consider only such as are readily and cheaply obtainable by the farmer and ranchman and those most practical in application.

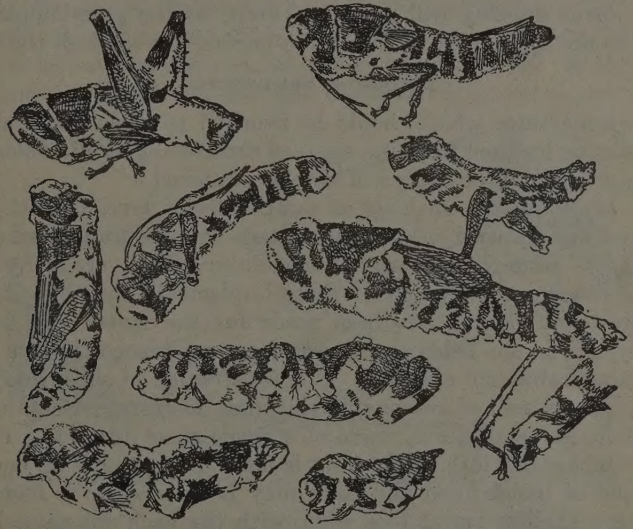

FIG. 7.—Grasshoppers killed by fungus, *Sporotrichum globuliferum*. (After Bruner.)

DESTROYING THE EGGS.

Destroying the eggs of the grasshoppers seems to be the only preventive measure that promises to be worth while attempting, except, perhaps, the destruction of the young as they are hatching. Destruction of the eggs may be accomplished by either plowing, harrowing, disking, or cultivating, in the fall or winter, all roadsides, ditch banks, margins of cultivated fields, uncultivated fields, and grassy margins along fences. In short, all waste lands that it is possible to reach in this manner should receive attention, unless it is known that no eggs were deposited there.

The soil need not be stirred deeply, 2 inches being a sufficient depth to accomplish the desired effect; and circumstances will probably dictate the kind of tool or tools that a farmer ought to

use and where to use them. There is no doubt whatever that if this measure were put into operation at the proper time, in whatever manner is most practicable, disastrous outbreaks the following spring would be forestalled and prevented. Except in cases of isolated farms or ranches, there should by all means be concerted action in this movement.

Where fields can be quickly inundated and the water promptly run off, as is frequently done in rice fields, the young grasshoppers may be killed by flooding the field for a day or two just as the eggs are hatching. If close watch is kept to determine just when the young grasshoppers are hatching, and prompt action taken at this time, much good can be accomplished; but as soon as the young begin to move about flooding will avail but little, as the grasshoppers will climb to the upper part of vegetation beyond the reach of the water.

DESTROYING THE INSECTS.

Those measures which should be resorted to when the grasshoppers, having hatched from the egg, are threatening alfalfa fields from within or without, or both, will now be discussed.

The hopperdozer.—On level or comparatively level land the hopperdozer can be used to good advantage in collecting grasshoppers of all ages—from the youngest to the adults. There are many modifications in the construction of these implements, but the form here described and figured has been made for the writer, and he has employed it in the fields and knows from experience that its use is both practicable and efficient. It is constructed of sheet iron, preferably galvanized, of reasonable thickness to insure strength, and, except for the end pieces, made of a single sheet 10 or 12 feet long and 26 inches in width. The front is formed by turning up one edge a couple of inches, and the back may be turned up a foot, thus making a shallow pan 1 foot wide, with the back the same height and with a front 2 inches high. Ends are riveted in and soldered, as shown in figure 8. Runners of old wagon tire are placed at each end (*a*, *b*), and another in the center (*c*) is turned over in the front and back to strengthen the pan at these points. These runners are riveted to the pan, as shown, and should extend both backward and forward in order to overcome to some extent the inequalities of the ground and cause the hopperdozer to run more smoothly. By soldering it about the heads of the rivets the pan will be made water-tight. The pan is filled with water, on which is poured enough kerosene to cover it with a film, a horse is hitched to the end runners, and the outfit is then ready for use. As the hopperdozer is drawn over the ground the locusts will either jump into the kerosene and water direct or against the back and drop into it and there be killed. By using longer, wider, and heavier sheet iron a larger and stronger pan

can be made and this further strengthened by additional runners; a horse can then be hitched to each end, or the pan may be mounted on low wheels. The whole thing is easily constructed, inexpensive, and once made may be put into service year after year as needed. The only place where its use will prove more or less impracticable will be on hilly or rocky lands or on that not yet cleared of stumps.

Poisoned baits.—In the use of poisoned baits we have another inexpensive, practical way of dealing with these grasshoppers even when, as is frequently the case, they breed in the alfalfa fields, and the protection, whatever it may be, must be applied there. What has come to be known as the "Criddle mixture" is giving most satisfactory results on the ranches of both the United States and Canada. The mixture is composed of half a barrel of fresh horse droppings in which is mixed 1 pound each of salt and Paris Green. If the horse droppings are not fresh, the salt is dissolved in water and mixed

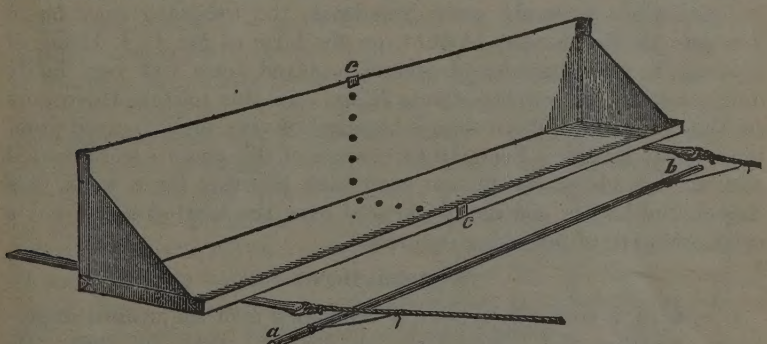

FIG. 8.—"Hopperdozer." A simple coal-oil pan, to be drawn by horse. (After Riley.)

with the manure and poison. When this mixture is scattered freely about where the grasshoppers are abundant, they seem to be attracted to it, for they devour it readily and are poisoned thereby. Dr. James Fletcher, late entomologist for the Dominion of Canada, cited an instance where this mixture had been scattered freely around the edges of a field, and stated that this particular field stood out as a green patch in a brown plain, as it was situated in the midst of fields where nothing had been done to destroy the grasshoppers.

Another effective bait is made by mixing wheat bran, 25 pounds; Paris green, 1 pound; cheap molasses or sirup, 2 quarts; oranges or lemons, 3 fruits. Thoroughly mix together the bran and Paris green. An ordinary washtub will answer for this purpose. Into a separate receptacle containing the molasses or sirup, squeeze the juices of the fruit; then chop up finely the skin and pulp of the fruit and add this also to the molasses mixture; then dilute with 2 gallons of water. Mix the two together and add enough more water to bring the

whole to a stiff dough. This amount of poison bait is sufficient to treat from 5 to 10 acres when properly applied. It should be borne in mind, however, that the fruit is the essential element of this bait, and if not employed 75 per cent of the efficiency of the bait is lost.

This poison bait should be applied to the area to be treated early in the morning, before sunrise. To obtain the best results the bait must be sown broadcast in strips 1 rod apart over the area to be treated. Broadcasting obviates the possibility of horses, cattle, sheep, poultry, or birds being able to obtain a sufficient amount of poison in the field to kill or injure them. Under no circumstances should the bait be scattered over treated areas in piles or bunches, for fear that birds or live stock might, under such circumstances, eat an injurious or fatal amount of the poison.

To illustrate the degree of safety with which the poison bait may be used when properly sown broadcast, the following may be of interest: In the summer of 1914, on the farm of Mr. C. I. Hood, of Chelsea, Vt., the pasture of several hundred acres was very badly infested with *Melanoplus atlanis* Riley. In this pasture there were continually grazing more than a hundred of very highly prized pure-bred Jersey heifers. From 10 to 15 acres of this pasture were treated with 25 pounds of the poison bran each morning for a week, and though the heifers continually grazed over the treated areas, not a single instance of poisoning occurred.

COOPERATION.

Cooperation between farmers or ranchmen is of the utmost importance, whether the hopperdozer or poisoned baits be used. On some of the more extensive ranches the owners can protect themselves by reason of the great extent of territory that is under the control of a single individual, but among smaller holdings cooperation is very essential.

FORESTALLING OUTBREAKS.

Forestalling of outbreaks would be spoken of by the ranchman as "watching out for trouble." By this is meant the careful watching of the fields for the appearance of the grasshoppers. When these are found to be present, do not wait to see what they are going to do, but prevent their doing any thing by putting into practice, before any damage has been done and while the grasshoppers are very young, whatever measures are to be used. It usually requires several days to poison the grasshoppers, and large areas can not be traversed with the hopperdozers in a day. Therefore if measures are to be successful they must not be delayed.

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U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

639

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.
December 19, 1914.

ERADICATION OF THE CATTLE TICK NECESSARY FOR PROFITABLE DAIRYING.

By J. H. McClain,
Of the Dairy Division.

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The cattle tick is a great hindrance to the development of the cattle-raising industry in the South. The sight of ticks on cattle is so common that many farmers do not regard them as harmful, and it is well known that a few ticks may remain on cattle quite a long time without doing any noticeable damage. The ticks, nevertheless, are the carriers of Texas fever, and even in so-called immune cattle they irritate the skin and draw blood that would otherwise produce milk or flesh. The actual amount of harm which ticks do to these so-called immune cattle has been a matter of conjecture. The need of some definite knowledge on this subject led the Department of Agriculture to conduct some experiments on the effect of the tick on milk production and body weights of dairy cattle.

The work was done by the Bureau of Animal Industry in the summers of 1912 and 1913 in cooperation with Mr. E. J. Thornhill, at Summerville, S. C., and Mr. E. C. Beuchler, vice-president and manager of the farm of the Anthony Farms Co., Anthony, Fla.

RESULTS OF EXPERIMENTS.

Forty cows were divided into two lots of 20, each of which was producing practically the same amount of milk and was given the same feed and care for an average of 152 days during the season favorable to the development of ticks. One of the lots in each experiment was allowed to become infested with ticks, while another was kept free from them in one case by spraying and in the other by dipping. The main results of the experiments were as follows:

1. Cows carrying ticks did not hold up so well in milk flow as the cows kept free from ticks and did not increase their flow of milk when the feed was increased, as did the tick-free cows.

2. At the close of the experiment the cows lightly infested with ticks were producing 18.6 per cent less milk than the cows kept free from ticks, practically 1½ pints less per cow per day.

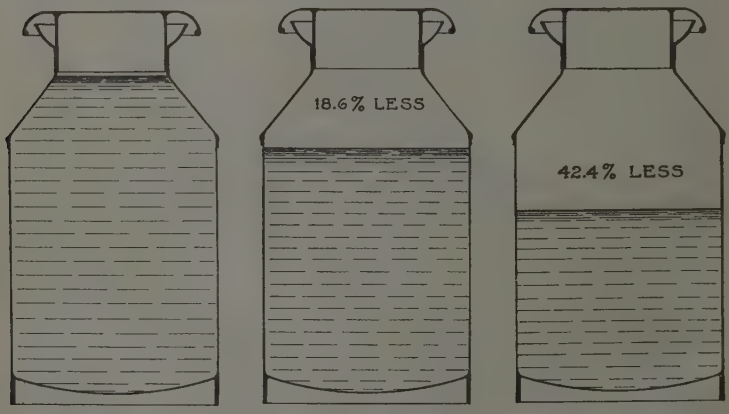
3. At the end of the experiments the cows heavily infested with ticks were producing 42.4 per cent less milk than the tick-free cows, or nearly one-half gallon less per head per day.

4. During the experimental period of one of the tests, which included 20 cows, the heavily infested cows lost an average of 9.3 pounds in weight, while the tick-free cows gained an average of 44.2 pounds, although both lots were fed alike.

5. Cows which had previously been infested with ticks and were supposed to be immune suffered from tick fever and one cow actually died from the effects of the tick.[1]

EFFECT OF SPRAYING AND DIPPING.

Some of the cows in the experiment were kept free from ticks by spraying with an arsenical solution (tick dip B) and the others by dipping in a similar solution in a dipping vat. The spraying caused



Milk produced by tick-free cows. Milk produced by lightly infested cows. Milk produced by heavily infested cows.

FIG. 1.—Relative quantities of milk produced by tick-free, lightly infested, and heavily infested cows.

a temporary falling off of 6.1 per cent in milk, but in from three to five days the bad effects of the spraying disappeared. Likewise, the shock of dipping caused the cows to lose an average of 10.6 per cent in milk for two days, but after several dippings they seemed to become accustomed to going through the vat and temporarily lost only 1 per cent in milk after the last few dippings. It should be remembered that while the dipping and spraying caused these temporary losses, they are very small, and it is by this means that the ticks are destroyed and a saving in milk effected in the long run.

While these experiments were conducted with comparatively small numbers of animals, the work was done with native cows on farms

[1] For a detailed account of these experiments, see Department Bulletin 147.

in the tick belt and are true indications of the great losses that occur annually with the thousands of cows exposed to the ravages of the cattle tick.

THE COST OF FEEDING TICKS.

If a dairyman with 20 cows, producing 8 quarts of milk each per day, should let them become lightly infested with ticks and the milk production were decreased, as in the case of the lightly infested cows in the experiments made by the Department of Agriculture, the loss would be 1½ quarts a day for each cow. At 20 cents a gallon, or 5 cents a quart, this would amount to 7½ cents a cow, or $1.50 for the entire herd each day. If the tick infestation were heavy and the reduction in milk were as great as in the heavily infested cows in the

FIG. 2.—A concrete vat for dipping cattle. This vat was made according to specifications furnished by the Bureau of Animal Industry, United States Department of Agriculture.

experiment, the loss would be 3.4 quarts (worth 17 cents) a day for each cow; this would amount to $3.40 a day for the entire herd.

The experience of a dairyman in the heart of the tick-infested territory also strikingly illustrates how much it costs dairymen to have ticks on their cattle. Late in the season, when his cows were covered with ticks, the cattle were dipped and the ticks killed. One week after dipping, the 42 cows in his herd gave 10 gallons of milk more than before dipping. This was an increase of 16.6 per cent, and as the milk was bringing 35 cents a gallon, the extra 10 gallons were worth $3.50; hence, by getting rid of the ticks, the same cows on the same feed produced enough milk to net the dairyman $3.50 a day more than before they were dipped. The money which this dairyman spent in dipping his cows was a good investment.

THE CATTLE TICK MUST BE ERADICATED.

If the farmers in one county will work together, the ticks in the entire county can be eradicated in one year. The dipping vat makes the work easy, effective, and practical. Methods of exterminating the tick are described in Farmers' Bulletin 498, which can be had on application to the United States Department of Agriculture, Washington, D. C.

It costs more to feed the ticks than it does to kill them.

Which do you prefer to do?

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 640 MARCH 17, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE HESSIAN FLY.[1]

By F. M. WEBSTER,

In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

Probably no other insect causes more damage to the wheat crop of the United States than the Hessian fly, though the chinch bug is doubtless a close second. During years when it is excessively abundant, hundreds of thousands of acres of wheat may be either

FIG. 1.—The Hessian fly (*Mayetiola destructor*): Adult female. Much enlarged. (Author's illustration.)

totally destroyed or so badly injured as to reduce the yield 50 to 75 per cent, and the monetary losses expressed in dollars would run far up into the millions. This insect has long been known to ravage

[1] *Mayetiola destructor* Say; order Diptera, family Itonidæ.

NOTE.—This bulletin is of interest in all the grain-growing sections of the United States, but especially in the regions shaded in the distribution map (fig. 8, p. 7). It is a revision of Circular No. 70 of the Bureau of Entomology.

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our wheat fields, yet farmers are, in many cases, still at a loss regarding the best methods of warding off its devastation.

EARLY HISTORY IN AMERICA.

The common name, "Hessian fly," was long ago bestowed upon this insect by Americans, because of its having committed some depredations on Long Island, New York, in 1779, in the vicinity of Lord Howe's old encampment of three years before. The Hessian mercenaries who constituted a part of this army were much despised, both at home and in America, and, on the supposition that these soldiers had brought the pest with them from their native country in the straw used for their bedding while en route, it was given the obnox-

FIG. 2.—The Hessian fly: Adult male. Much enlarged. (Original.)

ious name of "Hessian fly." Whether or not this theory of its introduction was well founded can never be either substantiated or disproven, and all that can now be said is, that the pest was imported, probably from some trans-Atlantic country and some time during the latter half of the eighteenth century. As a matter of interest, it may be stated that, in some quarters, the more ignorant Tory element of those days claimed that General Washington was responsible for this pest. It was not technically described until 1817.

DESCRIPTION OF THE INSECT.

The fly itself (fig. 1, female; fig. 2, male) is very small, being only about one-tenth of an inch long, the body of an obscure dark color, and the form much like that of a very small mosquito. The abdomen of the female (fig. 1) is red, or yellowish when first hatched from

the "flaxseed," the color varying with age, the posterior segments terminating in a compressed cylindrical, very minutely hairy ovipositor, capable of great extension. The male (fig. 2) is smaller, more slender, and in color generally darker than the female, the abdomen terminating in a somewhat intricate organ composed of a set each of outer and inner claspers.

The egg (fig. 3) is very minute, being only about one-fiftieth of an inch in length, cylindrical, roundingly pointed at the ends, glossy translucent, and slightly reddish, this color deepening with development.

The larva or maggot (fig. 4), when newly hatched, is a little smaller than the egg, with a slightly reddish tinge; later, as it increases in size, it is at first white and afterwards greenish white, clouded internally by flaky white.

After the larva has reached its full growth and the skin has hardened and turned brown, forming a covering known as a puparium, the insect is known as the flaxseed (fig. 6). There is at this time a minute, brown, forked process on the underside of the anterior end of the larva, known as the "breastbone" (fig. 5), the use of which is not fully understood. It is not present, however, until the larva enters the flaxseed state. Within this "flaxseed" it transforms first to a pupa (fig. 7), and from this to an adult fly. The term "flaxseed" is applied partly because of its brown color and partly because it is more or less flattened, thus giving it somewhat the appearance of a flaxseed.

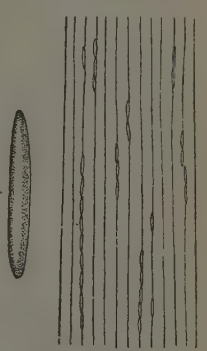

FIG. 3.—Egg of Hessian fly, greatly enlarged; section of leaf of wheat, at right, showing eggs as usually deposited, less enlarged. (Author's illustration.)

WHERE TO FIND THE DIFFERENT STAGES.

From the foregoing descriptions it will be observed that during the life of this insect it is found in four very different forms, so entirely unlike in appearance as to confuse the average farmer.

The eggs (fig. 3), which may be easily seen by one with fairly good eyesight, are generally placed in the grooves of the upper surface of the leaves, though they are occasionally found on the underside of the leaf. When the young wheat plant is just pushing through the ground, the egg is sometimes placed on the outside, because no leaves are available.

The young larva is slightly smaller than the egg, and as soon as it is hatched it makes its way down the leaf and behind the sheath. In case of young wheat it descends to just above the root, but after the plants have begun to joint it can go no farther than the base of the sheath belonging to that particular leaf, which is always at the

joint. Where excessively abundant, the larvæ will frequently be found on the lower stem ranged one behind the other, the anterior end of one pushed slightly under the posterior end of the one in advance. Very often this position is maintained throughout the entire development of the larva (figs. 4 and 5), and the flaxseeds (figs. 6 and 10) still retain the same relative position.

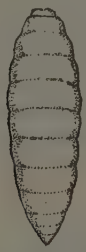

FIG. 4.—The Hessian fly: Larva before "flaxseed" is formed. Much enlarged. (Author's illustration.)

The fall generation of larvæ and the overwintering flaxseeds are to be found just above the roots (fig. 10), except in cases where the young plant has become disintegrated and separated at the point of attack in the fall or the plants have been heaved out by the action of freezing and thawing, in which case they may be scattered about on the surface of the ground.

The young make their way down the plant head foremost, and so remain until before pupating, when they reverse their position in the flaxseed and are then situated head upward, and thus pass into the pupal stage. Before the fly issues, however, if the flaxseed is not situated conveniently for its escape, the pupa will push itself, if possible, to such a point, and frequently empty pupa skins may be observed protruding from under the sheaths of the leaves.

FIG. 5.—The Hessian fly: Larva taken from "flaxseed." Much enlarged, with "breastbone" still more enlarged at right. (Author's illustration.)

The fly itself is not easily observed until one becomes familiar with its appearance, and this will account for the great variety of insects that are continually mistaken by farmers for the Hessian fly. Much of this difficulty may be obviated if farmers will look for an insect like that shown in figure 1, but very minute and somewhat resembling a very small mosquito. During warm days, in the egg-laying season, the flies may be observed flying about in the young wheat, alighting upon the leaves. In cooler days, or in early morning while a heavy dew is on, they will be down among the leaves, or even on the ground.

LIFE HISTORY.

At present all indications point to the probability that the Hessian fly has two generations, at least during favorable seasons, over its entire area of distribution in the United States.

In the South the two generations are the most widely separated, while in the North, in the regions of spring-wheat growing, one seems to follow the other in quick succession.

LIFE HISTORY IN REGIONS OF FALL-WHEAT GROWING.

Throughout the fall-wheat-growing sections the fly passes the winter in the young wheat, mostly in the flaxseed stage, but also to some extent as from two-thirds to full-grown larvæ. It is difficult to estimate the number of these larvæ that will winter over and remain alive until spring, owing to the fact that it is impossible to determine whether they are alive or dead until they begin to decay. But where we have attempted to rear them, even though apparently alive, comparatively few adults have been obtained, though, of course, this mortality would probably vary somewhat with the severity of the weather during winter.

FIG. 6.—The Hessian fly: Puparium or "flaxseed." Much enlarged. (Author's illustration.)

In spring (from March in Georgia and South Carolina to May in Michigan) the flies escape from the flaxseeds and deposit their eggs on the wheat, and the young from these develop to flaxseeds before harvest, passing the summer in the stubble. The flies from over-wintering larvæ come on later, and it is quite probable, also, that some of the very earliest deposited eggs may give rise to adults at about this time. Thus, owing to this overlapping, during some seasons and in some localities, there appears just before harvest what has by some been considered a supplementary second generation.

In autumn the time of appearance of adults as between North and South is reversed. In northern Michigan the adults of the fall generation are abroad, under normal meteorological conditions, during the last days of August and first days of September. In Georgia and South Carolina, under the same conditions, it may be the last of November or the first of December before they have all left the stubble. Thus has the species adapted itself to the prolonged southern summer, during which there is little or no food for the larvæ. While there are stragglers, the major part of the generation will appear and disappear within the space of a few days, probably within a week, and the flies, by preference, will deposit their eggs on the younger plants, those of one or two leaves seeming to suit them best. At this time the young larvæ make their way downward nearly or quite to the roots (fig. 10). The normal outcome of this generation is that the individuals reach their development as larvæ, pass into the flaxseed stage, and pass the winter as such on the young wheat plants. But here again the earliest deposited eggs may produce adults before the winter sets in, and the delayed individuals

FIG. 7.—The Hessian fly: Pupa taken from "flaxseed." Greatly enlarged. (After Marlatt.)

occurring at this time may unite, and another supplementary generation, as it has been termed, may be produced. The economic significance of this so-called generation depends much on the weather, as, if winter sets in before the larvæ have sufficiently matured to withstand its rigors, these must necessarily perish, while if the mild autumn weather is greatly prolonged, a greater or less number of them may winter over uninjured.

LIFE HISTORY IN SPRING-WHEAT REGIONS OF THE NORTHWEST.

The statements here made regarding the life history of the Hessian fly in the spring-wheat regions of the Northwest are based largely on the careful investigations carried out by Mr. George I. Reeves, a special field agent of the Bureau of Entomology, during the season of 1905. This single season may have been an exceptional one, in that the spring was backward, the summer wet, and the mild autumn weather continued later than usual. The results must not, therefore, be taken as wholly conclusive.

In North Dakota the insect winters in the flaxseed stage in both stubble and volunteer wheat, chiefly the former. Egg laying begins late in May, and during seasons with plenty of rain the second generation follows the first in quick succession, being reenforced by the continued emergence of flies from stubble of the previous year. Here the summer conditions are different from those in the East and South, and the breeding season extends from about May 20 to October 1, or throughout the entire summer. In other respects the habits of the insect do not seem to differ from what they are in the fall-wheat-growing sections of the country.

DISTRIBUTION.

Outside of America the Hessian fly occurs in North Africa, western Asia, Europe, British Islands, and New Zealand. In the Dominion of Canada Fletcher found it from Prince Edward Island to Indian Head, Saskatchewan. On the Pacific coast it probably occurs from central California to British Columbia; but as no exact investigations have been made there, this statement is to be considered as only approximately correct.

Our previous notions of the distribution of this insect over the country east of the Rocky Mountains will have to be revised. The accompanying map (fig. 8) shows the extent to which this revision becomes necessary.

The dotted area indicates the present distribution of the Hessian fly based on our latest observations and data furnished by Prof. Lawrence Bruner, of Nebraska, and Mr. R. I. Smith, entomologist of the Georgia State crop pest commission. This is believed to be approximately correct. It also seems to show that the insect must

have been first introduced into the Pacific coast region in or with articles of inland commerce, and, unless it be found to infest native grasses, that it did not reach there by natural diffusion, a point that has not before been definitely stated so as to be clearly understood.

Experimental sowings of wheat near Sault Ste. Marie, Mich., during the years 1904 and 1905 do not reveal its presence there, and no attempt has been made to study its occurrence in the spring-wheat-growing sections of Maine. While its absence in some parts of the country between the Platte River, in Nebraska, and the Canadian boundary line might be attributed to a lack of its food plant, this will not hold in southwestern Kansas and Oklahoma, as in those localities it seems to terminate suddenly in the midst of a wheat-growing sec-

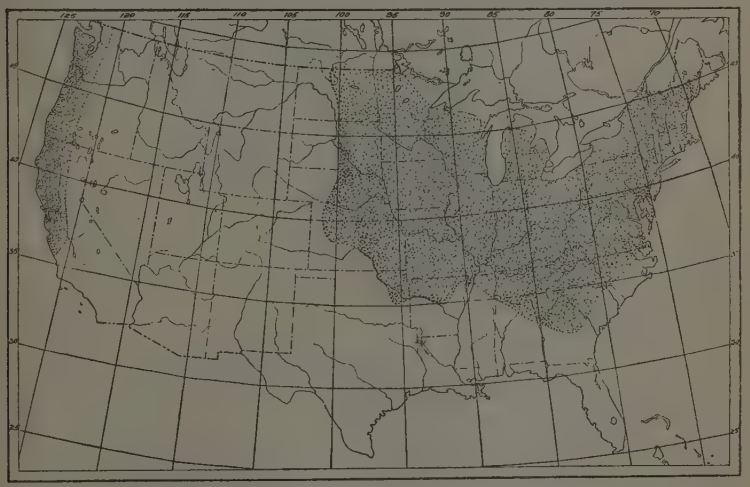

FIG. 8.—Map showing distribution of the Hessian fly in the United States in 1914. (Original.)

tion, and where this grain has been cultivated for at least twenty years. Strange as this may at first appear, Dr. C. Hart Merriam, formerly Chief of the Biological Survey of the U. S. Department of Agriculture, informed the writer that he has found several parallel cases in the distribution of some of the smaller mammals.

FOOD PLANTS.

The chief food plant of the Hessian fly is wheat, next to this barley, and lastly rye. In the last plant, however, it does not develop freely, and it does not attack oats at all. Many years ago Lindemann, in Russia, found what he determined as the flaxseeds of the Hessian fly on timothy and *Agropyron repens*. Later Mr. Albert Koebele found flaxseeds closely resembling those of the Hessian fly on Elymus, Agrostis, Bromus, and Agropyron in California. Still later

Mr. W. J. Phillips found similar flaxseeds in Agropyron about Richmond, Ind., May, 1908. During September of the same year Mr. E. O. G. Kelly found the Hessian fly breeding in abundance in *Agropyron smithii* in the vicinity of Wellington, Kans. This appearance of the Hessian fly in this grass during 1908 and 1909 was very marked

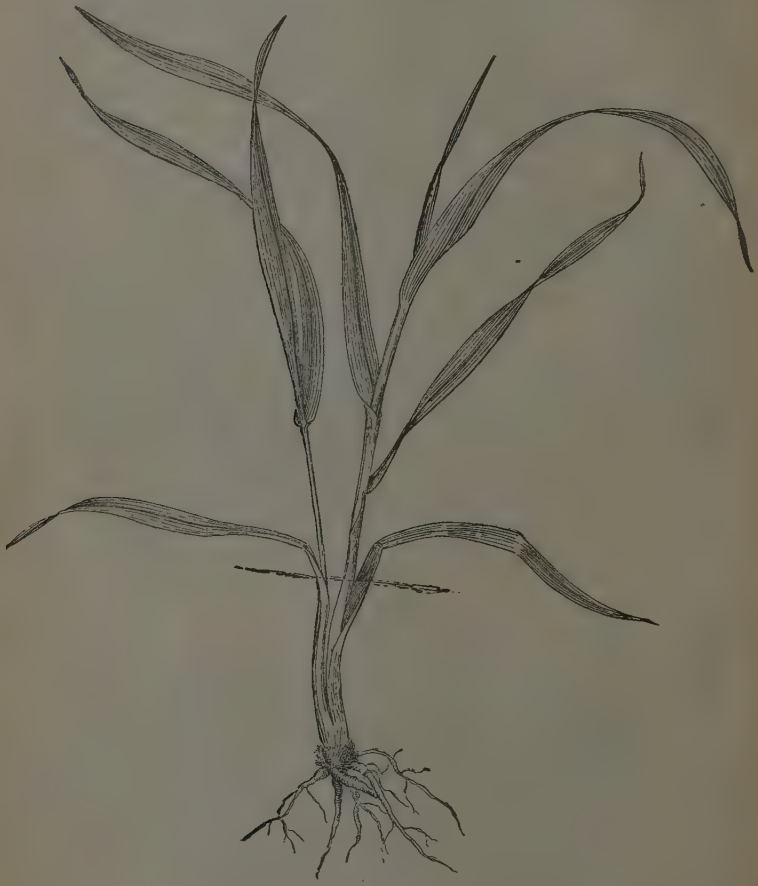

FIG. 9.—Healthy young wheat plant. (Author's illustration.)

indeed, owing to the fact that the grass was growing within the Chicago, Rock Island, and Pacific Railway right of way. The dried grass was burned off, so that the fresh growth came up just at the time that the Hessian flies were abroad depositing their eggs. The young grass plants were not only abundant but convenient and the flies

utilized them, placing an enormous number of eggs on the upper surface of the leaves, precisely as is their wont in the case of grains. The larvæ, after making their way down the sheaths and beginning to attack the plants, gave to them precisely the same appearance as infested wheat plants. Under these circumstances the Hessian fly appeared to breed as freely in *Agropyron smithii* as in wheat. On October 25 of the following year Mr. G. I. Reeves found many Hessian fly eggs and larvæ in all stages of development up to the flaxseed on *Agropyron repens*, and probably also on other varieties of this grass, growing up in the wheat fields in the vicinity of Vancouver, Wash. Mr. C. N. Ainslie found the flaxseed stage of the Hessian fly in *Agropyron tenerum* growing in alleys at Elk Point, S. Dak., June 23, 1913. There is therefore no doubt whatever but that the Hessian fly will breed in Agropyron, and perhaps also, in some portions of the country, to a limited extent, in Elymus, Agrostis, and Bromus. Dr. S. A. Forbes a number of years ago failed to induce the fly to breed in either redtop, bluegrass, foxtail, or orchard grass.

EFFECT OF LARVÆ ON THE PLANT.

The effect of the larvæ on a young wheat plant is very marked and becomes observable soon after the young reach the stem under the sheath. Once he has observed it, any farmer can readily detect an infested plant, or a single infested tiller may be as readily detected in a cluster without taking the trouble to remove the plant from the ground.

For the purpose of comparison, illustrations are given of an uninfested young plant (fig. 9) and an infested young plant (fig. 10). An uninfested plant is of a more slender growth, the green color is lighter, with a slight tinge of yellow, the stems are more or less visible, and the central unfolding leaf is present. The whole plant is inclined to droop and the tillers spread out and cover the ground. An infested plant is without stem and the leaves are broader, usually shorter and of a deep bluish-green color, somewhat resembling those of oats. The plant stands more erect, and, in fact, is but a mass of short overgrown leaves that usually kill with the first frost. Figure 10 shows a young tiller starting out from below the part attacked by the fly. If this tiller were to be attacked after it appeared above ground, there would follow the same appearance as in case of the original plant; that is to say, the leaves would become broader and of a darker color. The foregoing statement will apply to a severe attack on fall wheat in spring and on young spring wheat. The only exception in the appearance of infested young plants is in the case of the hard wheats, whose foliage is broader and of a darker color, but the erect position will still enable the observer to detect the infestation. Of course later on

the infested plants change to yellow and then brown, but the darker color and rank growth of leaf always precede this.

In summer, in both spring and fall wheat, the effect of the fly is to cause the straw to break over before harvest. It is then said to be "straw fallen."

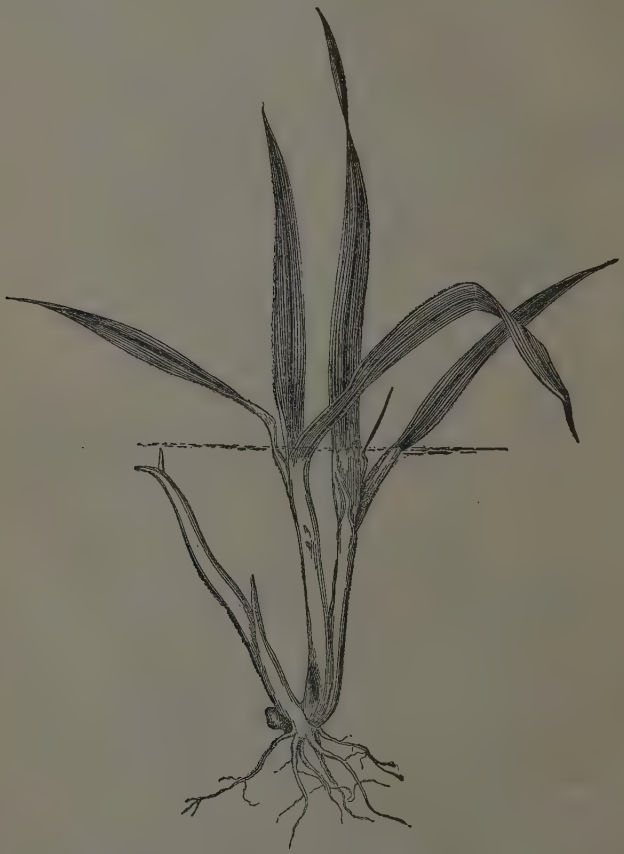

FIG. 10.—Young wheat plant infested by the Hessian fly. (Author's illustration.)

IMMUNE OR DISTASTEFUL VARIETIES OF WHEATS.

There is no such thing as "fly-proof wheat." Most wheats will suffer when the plants are young, regardless of variety. In experimental sowings a variety that seems to escape attack one year may suffer the next; and, while the insect may prefer certain varieties over others, this all comes to naught in years of serious ravages or where the sup-

posed distasteful variety is in a condition more satisfactory to the insect at the time of oviposition. It is doubtful, however, if this can be said of the attack of the second brood on the more matured plants, as it is quite noticeable that the ranker-growing varieties with strong, stiff straw are the least affected. Then, too, among fall wheats in the northern part of the country it is quite essential that a wheat plant be able to send out tillers from the old roots of plants killed by the fly (fig. 10), and that these tillers prove hardy enough to withstand the winter. Therefore, in selecting varieties of wheat with a view to evading Hessian-fly attack, the farmer will do well to ignore statements on this point from those who have seed to sell and select from the varieties known to do well in his locality such as are of strong, vigorous growth, hardy, and with a stiff straw.

For some reason the durum wheats do not seem to attract the fly, at least not the second brood. In going over fields of this kind of wheat in sections where other spring wheats were suffering from attack by this pest, it was rarely found on a stem of durum wheat, while any straws of other varieties growing from seed that had become intermixed were almost invariably infested. Whether this will hold good in case of the young plants it is as yet impossible to say, because of the difficulty of telling to what varieties the young plants belong. Infested plants have been found in fields of young durum wheat in some considerable numbers; but these plants may have been of other varieties, as the fields had been used for other varieties the year before, and besides the seed itself may have been impure.

METEOROLOGICAL EFFECTS.

All who have carefully studied the Hessian fly under various field conditions during a series of years have noted that weather conditions have an important influence on the insect. Especially is this true in its economic relations to the grains it attacks; hence in the application of preventive measures these weather conditions become of vital importance.

Many farmers place much stress on the effect of cold weather or even of frosts in terminating the flies' work in the fall, and it is for this reason that many try to delay wheat sowing until after there has been a sharp frost. The facts are that the females will be abroad and ovipositing in freezing weather, and Mr. W. J. Phillips has found by experimentation that the eggs will remain in a temperature of 36° F. for seventy-two hours with no other effect than to delay their hatching that much longer. This is about the temperature at which frosts would occur. Indeed, the writer has observed eggs hatching during the day in the fields when there were frosts nearly every night. Whether or not the larvæ from these would get sufficiently advanced

to pass the winter would, of course, depend upon later weather conditions. In the North these much-belated larvæ are killed off by cold weather.

The immunity of the late-sown wheat from attack by the fly is not due to frost, but to the fact that by the time severe frosts usually occur most of the flies have appeared and gone.

The most marked influence of climatic conditions on this insect is seen in the effect of heat and drought, and especially of the two combined. In the South it is the long summer that so widely separates the two generations. Drought has a similar effect on the development of the insect as it has on the germination of the seed which produces its food; thus, dry weather in the late summer and fall tends to keep the insect in the flaxseed stage—a fact of special importance in the North where it is imperative to get the wheat sown early enough to enable the plants to stand the winter. Under exceptional conditions, such as in a dry room, flaxseeds may be kept for a year, or even two, but when moistened the flies will soon emerge. So in the fields they will, during a drought, remain in the flaxseed state for a considerable time after they would appear under normal conditions, and only appear soon after rains have moistened the soil.

The first publication [1] dealing with the generally uniform retardation of development of the fall generation from the north southward was based on work done by the author in Indiana during the years 1886 to 1890, with the aid of experimental plats sown throughout the entire length of the State.

Studies of the Hessian fly in Indiana, which were begun by the author in 1884, very soon indicated that information regarding the development of this insect based on information secured in the northern part of the State would not apply at all in the extreme southern section. So far as known to the writer, this publication is the first on record relating to this particular feature of the development of the pest. Later the same investigation was continued in Ohio.[2] The results of this work showed very clearly that the uniformity of development of the fall generation, which is the one most to be feared by the farmer, was practically the same in Ohio as in Indiana. Even at that time there was an indication of what might be termed a variation from the normal condition in southern Michigan.

Since 1904 similar wheat-sowing experiments have been conducted from northern Michigan and northern New York to central Georgia and across the State of Kansas. As a result of the sowings in Michigan it was found that owing to some influence, probably that of the

[1] Webster, F. M. Report on Some of the Insects Affecting Cereal Crops. The Hessian Fly. *In* U. S. Dept. Agr., Div. Ent., Bul. 23 (old series), pp. 63–79, 1891.

[2] Bulletin No. 7, Vol. IV, of the Ohio Agricultural Experiment Station, published in 1891; Bulletin No. 107 of the same institution, published in 1899; and Bulletin No. 119, also of the same institution, published in June, 1900.

Great Lakes, the farmers of the southern half of southern Michigan could not sow their wheat with safety earlier than the farmers of northern Ohio, say 50 miles to the southward. It is to be pointed out that while east of the Alleghenies the Hessian fly extends from Canada southward to central Georgia, west of the Mississippi River it extends from Canada southward only to northeastern Oklahoma. (See map, fig. 8.) Over the area east of the Mississippi River climatic conditions, due seemingly to latitude, have had the effect of retarding the development of the adult flies in the wheat stubble and their consequent appearance preparatory to egg laying in the fall for a period covering considerably over one month as between southern Michigan and southern Georgia. As a matter of fact, humidity, or the lack of it, seems to be a vastly more important element in influencing the distribution and development of the Hessian fly than either altitude or latitude. In proof of this, during seasons when the wheat crop of Sumner County, southern Kansas, was in many cases totally destroyed by the Hessian fly, at Enid, Okla., approximately 40 miles away to the southward, it was only by the most diligent search that occasional individuals could be found in the wheat fields. The country between these localities is almost exclusively devoted to wheat, so that there was no lack of food plants, and the topography of the country is very much the same, the elevation of Enid being almost exactly that of Wellington. Not only did this condition obtain in the year 1907, but it was practically determined three years earlier by Mr. George I. Reeves, who made a survey of the distribution of the Hessian fly in that part of the country in the fall of 1904. The conditions up to the present remain unchanged. Furthermore, as observed by Mr. E. O. G. Kelly, with the Hessian fly common at Kinsley, Kans., altitude 2,164 feet, and located 36 miles east of Dodge City, and destructively abundant at Great Bend, elevation 1,843 feet, 82 miles northeast of Dodge City, and at Larned, elevation 1,995 feet, 60 miles from Dodge City and located between Great Bend and Kinsley, careful search at various times by several assistants of the Bureau of Entomology have utterly failed to reveal a single individual Hessian fly in the wheat fields at Dodge City, elevation 2,480 feet, with wheat growing continuously between this point and Great Bend, Larned, and Kinsley.

In the spring of 1913 wheat plants carrying approximately 1,200 flaxseeds of the Hessian fly were transplanted by Mr. Kelly from Sedgewick, Kans., to Dodge City, placed in a rearing cage with mesh sufficiently fine to retain the adult insects, and put in the fields April 9, 1913, under as exact field conditions as it was possible to obtain. This cage was allowed to remain in place until May 22, after there had been ample time for the flies to emerge and oviposit, whereupon it

was removed. As a result of this experiment, from all of the flies developing from the transplanted wheat the offspring numbered but four individuals, showing quite conclusively that the Hessian fly can not develop in destructive abundance in that locality. This insect is destructively abundant west of the Cascade Mountains in Washington and Oregon, but not in the semiarid section to the eastward.

The distribution of the Hessian fly seems, therefore, to be controlled to a certain extent in the United States by conditions of humidity. Furthermore, the development of the fall generation appears to be governed to a certain extent by the same factor.

NATURAL ENEMIES.

There can be no doubt that parasites play a most conspicuous part in the natural control of the Hessian fly, and if we only knew the whole truth of the matter we should find that these minute friends of the

FIG. 11.—*Polygnotus hiemalis*, a parasite of the Hessian fly. Much enlarged. (Original.)

farmer are worth many times their weight in gold. Not infrequently one species of these parasites will overcome the pest in a neighborhood so effectively as almost to exterminate it. Several times the writer has found, in attempting to breed the Hessian fly from young wheat plants that had been killed by the larvæ, that hundreds of these parasites would emerge from the flaxseeds, while only an occasional fly could be obtained. Nearly all of these deposit their eggs in the bodies of the maggots, but the fully developed parasites emerge from the flaxseeds.

Prof. Herbert Osborn [1] has enumerated six species of these parasites, not including the English species *Entedon epigonus* Walker.

[1] Osborn, Herbert. The Hessian Fly in the United States. U. S. Dept. Agr., Div. Ent., Bul. 16, 58 p., 2 pl., 8 figs., 1898. See p. 28.

Polygnotus minutus Lindm., which occurs in Russia, France, and England, is in America represented by *Polygnotus hiemalis* Forbes (fig. 11), perhaps the most useful of any in this country. It is very minute, and Mr. Reeves has counted over 40 of the larvæ within a single flaxseed. It is black, with yellow feet, and the legs are dark brown, banded with yellow. The writer has again and again reared this in great numbers from fall wheat infested by the fly and witnessed the sudden check sustained by the pest the following spring. It is owing to this more than to any other influence that the Hessian fly is now being held in check in the spring-wheat regions of the Northwest, and it is probably due to a lack of this useful little insect that the serious invasion of the Hessian fly during the year 1914 was primarily due. From all the information at present available the severe winter of 1912 and 1913 so greatly reduced its numbers as to relieve the Hessian fly from the enormous restraint that it was at that time exerting upon the pest. A vast amount of material was secured during the summer and autumn of 1914 from which this parasite could have been reared had it been present. From nowhere over the entire section of the country infested by the Hessian fly, excepting in the State of Pennsylvania, have we been able to rear the parasite, and it seems almost beyond doubt that the losses from attacks of the Hessian fly during 1914, and such as may occur during the year 1915, will be due to the absence of this parasite in the wheat fields. The occurrence of the adult within the flaxseed of the Hessian fly is illustrated in figure 12.

FIG. 12.—Adults of Polygnotus which have developed within the "flaxseed" of the Hessian fly and are ready to emerge. Greatly enlarged. (Author's illustration.)

What appears to have been a most successful introduction of this beneficial insect was brought about some years ago in a shipment by Mr. E. O. G. Kelly from the Wellington, Kans., laboratory, to Mr. George I. Reeves in the State of Washington. Mr. Reeves liberated these parasites in fields badly affected by the Hessian fly. Up to that time he had not been able to secure this parasite in the State of Washington, whereas since the introduction of this insect from Kansas it has become not only very common, but in some cases abundant.

Another parasite reared almost invariably in connection with the Hessian fly is *Eupelmus allynii* French. (Fig. 13, male; fig. 14, female.) While this is generally distributed over the country and seems to be associated with the Hessian fly, and was for a long time supposed to be parasitic thereon, it now seems possible that it may be a secondary parasite and therefore the reverse of beneficial. It may be said, however, in its defense that it is most certainly a very important parasite of some other grain insects, notably the jointworms

and wheat straw-worms. The body is black with a greenish luster, and the legs are more or less yellow.

Merisus destructor Say (fig. 15) occurs in Europe, England, and America, but not in such profusion with us as to afford the same relief to the farmer as in the case of the preceding two. It also is black, but with a bluish-green metallic reflection, and the legs are black, banded with yellow.

Platygaster herrickii Pack. (fig. 16) is very minute, shining black in color, and is supposed by many to attack the egg of the fly, but there is still some doubt regarding this.

Bœotomus subapterus Riley (fig. 17), as the name implies, has aborted wings in some individuals, while others are fully winged. The head

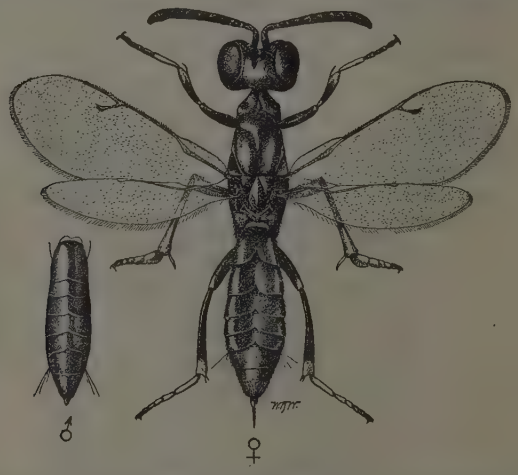

FIG. 13.—*Eupelmus allynii*, a parasite of the Hessian fly: Male. Much enlarged. (Original.)

and thorax are of a dark greenish metallic luster, and the legs honey-yellow. It is generally less abundant than some of the others, but sometimes individuals are quite numerous.

Besides these, several undescribed species have been recorded from the northwestern part of the country. The influence of these minute parasites in regulating the world's wheat supply is not at all understood, and it is doubtful if wheat could be successfully raised were they all to be suddenly swept out of existence.

REMEDIAL AND PREVENTIVE MEASURES.

Of remedies there is little to be said, since after the pest becomes established in a field it can not be reached by any measure likely to destroy it. The application broadcast of some quick-acting fertilizer containing a large percentage of phosphate, made as soon as general

infestation is apparent (see fig. 10), will cause the plants to tiller more freely and give them sufficient vigor to withstand the winter, and thus increase the number of healthy stems the following spring. Any other means that could be employed having a similar effect would be a remedial measure.

All practical measures must necessarily be in the nature of preventives, looking (1) to the elimination of the pest in the young wheat in the fall, and (2) to the increasing of the vigor of the young plants in order to enable them to counteract the insect's effect, when present. Under the first come late sowing, rotation of crops, burning of the old stubble, and the destruction of volunteer wheat. Under the second should be classed the enrichment of the soil, its thorough preparation, and selecting and properly sowing the best seed.

By late sowing as here recommended is meant moderately late sowing of fall wheat in any locality, for extremely late sowing, which has sometimes been advised, would be even worse than early sowing. The later appearance of the fly in the fall, as we pass from the north

FIG. 14.—*Eupelmus allynii*, a parasite of the Hessian fly: Female. Much enlarged. (Original.)

LATE SOWING.

southward, has already been explained. At present the Bureau of Entomology is conducting experiments in fall wheat sowing in nine States, covering approximately the country between latitude 33° and 46°. Here wheat is being sown every ten days during September, October, and November, year after year, with the expectation of determining the approximate date of safety for seeding in the fall to evade attack of the fly. While these experiments have not been going on for a long enough time to give results sufficiently definite, covering all variations in the weather during these months, it is safe to say that wheat may probably be sown, without danger from Hessian fly attack, in northern Michigan soon after the first of September; in southern Michigan and northern Ohio, about September 20; in southern Ohio, after the first week in October; in Kentucky and Tennessee, October 10 to 20; in Georgia and South Carolina, October 25 to November 15. In extreme southern Kansas and northern Oklahoma wheat should not be sown until after the first week in October; and this is true of Virginia. October-sown

wheat always enjoys the greatest freedom from the fly in Maryland. Practically the same corresponding delay in wheat sowing in the fall should be followed to the southward. So far these dates are only approximate, and serve to show in a general way about the time when the fall brood of the fly will have largely disappeared over the wheat belt east of the Mississippi River. As the larger part of the fall brood appears and is gone within a week, it is possible for a farmer so to time his seeding as to avoid it, and this is by far the most practical and effective preventive measure that can be applied.

CROP ROTATION.

Aside from the general benefits to be derived from crop rotation, this practice compels the Hessian fly, when it emerges from the

FIG. 15.— *Merisus destructor*, a parasite of the Hessian fly. Much enlarged. (Original.)

stubble in the fall (or spring in the Northwest), to travel a greater or less distance to reach young wheat plants.

If, during this season of migration, storms or heavy winds occur, these frail creatures will be driven about or beaten down until a comparatively small number survive to reach their destination. On the other hand, if they are not obliged to leave the field where they emerge, this mortality will be vastly lessened.

BURNING STUBBLE.

Burning the stubble is the most efficient measure of all, as fire will reach and destroy not only the Hessian fly but all other insects infesting the stubble, including the joint-worm. Unfortunately it can not be generally carried out. Over a large portion of the Middle West timothy and clover are sown, either with the wheat or during late winter or early spring, and therefore stubble-ground can not be burned over. Fields not followed by grass or clover can usually be burned over if the grain is cut rather high at harvest and a mower is

run over the field and the mown grass, weeds, and stubble allowed to dry for a few days just before the burning. This is much the more feasible measure in the Northwest, and ought to be more generally followed.

DESTRUCTION OF VOLUNTEER WHEAT.

Perhaps the importance of the destruction of volunteer wheat is best illustrated by the condition frequently observed in fields of young wheat in the fall, where every volunteer plant is infested and the sown grain is entirely free from attack. The volunteer plants were above ground in time to enable the fly to deposit her eggs on them, with the result that large numbers of flaxseeds will go through the winter and the flies therefrom will deposit their eggs on the plants which constitute the crop itself. Mr. C. N. Ainslie found 157 "flaxseeds" on a single volunteer wheat plant taken from a field in

FIG. 16.—*Platygaster herrickii*, a parasite of the Hessian fly. Much enlarged. (Original.)

southwestern Iowa in October, 1914. Thus the growth of volunteer plants menaces, to a certain degree, the crop of the following year, precisely as does a field sown too early more seriously menace adjoining fields that are uninfested in the fall. This destruction of volunteer plants by plowing, disking, or otherwise must take place before the larvæ have matured in order to be effective.

ENRICHING THE SOIL.

While it may seem "far fetched" to bring forward as a preventive measure the enrichment of the soil, a fertile soil will produce plants that will withstand with little injury attacks that will prove disastrous to plants growing on an impoverished or thin soil. This is because a fertile soil will enable an infested plant to tiller freely, and these tillers will have sufficient vitality to withstand the winter and send up head-producing stems in the spring. It is also chiefly on the thin or impov-

erished soils that the difficulty of sowing late enough to evade the fall attack and at the same time secure a growth sufficient to withstand the winter is encountered, and whatever can be done to obviate this difficulty will constitute a preventive measure.

PROPER PREPARATION OF THE SOIL.

It matters little whether a soil has much or little fertility if that fertility is bound up in clods or hard lumps out of reach of the rootlets of the young plants. Early plowing and thorough working and compacting of the soil will eliminate the lumps and clods and produce a finely pulverized, compact, moisture-conserving seed bed, from which, as soon as rootlets are sent out from the seed kernel, the shoot will begin to draw nourishment. This will give vigor to the plants and thus enable them, by freely tillering, to outgrow a light attack of the fly that otherwise might prove serious.

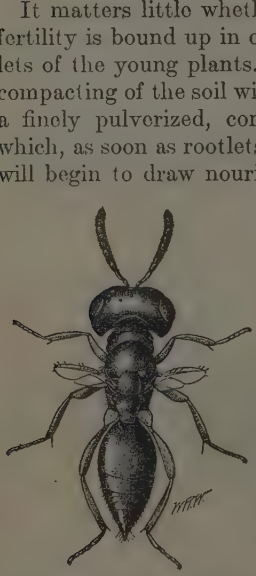

FIG. 17.—*Bracotomus subapterus*, a parasite of the Hessian fly. Much enlarged. (Original.)

THE USE OF GOOD SEED.

When we come to consider the fact that the seed kernel contains, or should contain, sufficient nutriment to put out and sustain rootlets until these can begin to draw from the soil and thus support the stem, it will be seen at once that any deficiency in the seed will necessarily tend to weaken the plant at the very beginning of its existence. Thus good seed becomes the first requisite in securing the healthy, vigorous plant that is to be further strengthened and sustained by a well-prepared, fertile soil. It is very clear, then, that all shrunken, dwarfed, or otherwise imperfect kernels should be cleaned out of the seed before it is sown and only the largest and most perfect retained.

CONCLUSION.

Methods for controlling the Hessian fly, the worst pest of the wheat field, in the fall-wheat-growing sections may be summarized as follows: Sow the best of seed in thoroughly prepared, fertile soil after the major portion of the fall brood has made its appearance and passed out of existence, and, if possible, sow on ground not devoted to wheat the preceding year.

In the spring-wheat section late seeding will not apply. It seems likely, on the contrary, that the earlier it is sown in spring the less it will suffer from the Hessian fly. But good seed and a well-prepared, fertile soil are as essential there as elsewhere.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 649 FEBRUARY 27, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

ALFALFA ATTACKED BY THE CLOVER-ROOT CURCULIO.

IMP. BUREAU ENTOM.
Rec'd. 18 MAY 1915

By F. M. WEBSTER,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The clover-root curculio[1] is of foreign origin and was not known to occur in America prior to 1876, when the late Dr. John LeConte found the beetles about the roots of grass growing on sand dunes at

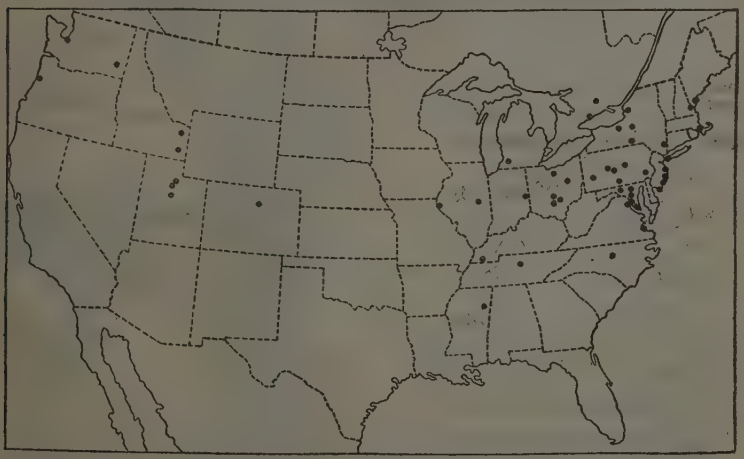

FIG. 1.—Present known distribution in the United States of the clover-root curculio. (Original.)

Long Branch, N. J. Just when and by what means it was first brought into this country will of course never be known. It has, however, become widely diffused over the United States, as indicated

[1] *Sitones hispidulus* Fab.

NOTE.—In this bulletin attention is directed to the serious injury to clover and alfalfa caused by the clover-root curculio, and a description of the insect, its feeding habits, and remedial and preventive measures are given.

on the accompanying map (fig. 1), showing its known distribution up to the present time.

Several years ago studies were made of the insect and its attacks upon clover, although up to that time it had not been known to destroy this crop, or even to affect it seriously. Apparently, however, it was likely to become sufficiently abundant at any time to work serious injury, and for this reason Mr. V. L. Wildermuth, an assistant in cereal and forage insect investigations, prepared a paper which was published on March 7, 1910, as a bulletin of the Bureau of Entomology.[1] At that time there had hardly sufficient evidence accumulated to give this paper any considerable economic importance. It seems, however, that injuries that had either remained unnoticed or else had been placed to the credit of some other pests were partly or wholly due to the work of the larva or grub of this beetle. As this insect shows a disposition to occur in continually increasing abundance along roadsides and in clover fields, and as it has, during the last year, been found to commit serious depredations in fields of alfalfa, it seems desirable that printed information be made available for distribution among farmers, who are likely to suffer more or less from ravages of the pest.

FIG. 2.—The clover-root curculio: Adult. Greatly enlarged. (From Wildermuth.)

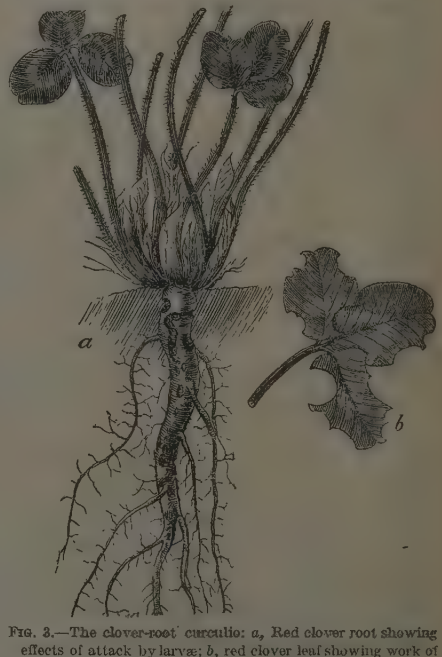

FIG. 3.—The clover-root curculio: *a*, Red clover root showing effects of attack by larvæ; *b*, red clover leaf showing work of adults. About natural size. (From Wildermuth.)

WHAT THE INSECT IS LIKE.

The fully developed insect is a beetle (fig. 2) which attacks the leaves of clover (fig. 3, *b*) and alfalfa. The line at the right of figure 2 shows the natural length of the beetle, and the eaten leaves (fig. 3, *b*) are plainly to be seen, especially during September

[1] Wildermuth, V. L. The clover-root curculio (*Sitones hispidulus* Fab.). U. S. Dept. Agr., Bur. Ent., Bul. 85, Pt. III, p. 29–38, fig. 15–19, March 7, 1910.

and October. They are particularly noticeable along roadsides, and the writer recently observed that in many cases the majority of the clover leaves in Middletown Valley between Mount Catoctin and South Mountain, Md., were eaten in this way, although the injury was not so noticeable in the clover fields adjacent. The most serious injury, however, is not to be charged to the beetle itself, but to the larva or grub.

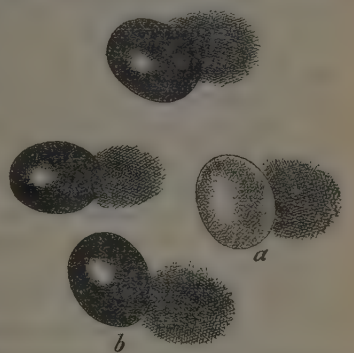

FIG. 4.—The clover-root curculio: *a*, Egg immediately after deposition; *b*, egg one day after deposition. Greatly enlarged. (From Wildermuth.)

The eggs (fig. 4) are almost spherical, minute, and when first deposited are white, but after 24 hours change to a jet black. These eggs hatch to an almost equally minute white larva (fig. 5), the head of which is of a light chocolate brown. These grubs are without feet and therefore can not travel about readily. It is in this stage that the insect attacks the roots of clover and alfalfa and is particularly injurious. When this grub becomes full grown it passes from the grub stage into what is known as the pupal stage (fig. 6) during which it requires no food and consequently is not then injurious.

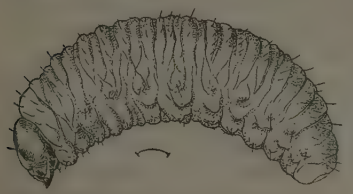

FIG. 5.—The clover-root curculio: Larva. Greatly enlarged. (From Wildermuth.)

SEASONAL HISTORY.

The clover-root curculio, as stated by Mr. Wildermuth, hibernates in the beetle form, hiding itself under rubbish and leaves on the surface of the ground, probably going into hibernation, in the latitude of Washington, some time in November. These beetles remain in their winter quarters until the first warm days of spring, when the females begin to lay their eggs upon the plants on the roots of which the young grubs are to feed. That these operations begin at the earliest possible date is shown by the fact that beetles were observed pairing near Hagerstown, Md., by Mr. H. L. Parker, on September 12, 1914, while Mr. Wildermuth found that beetles taken from the fields in October or November and kept in a warm room would produce eggs almost immediately; or if they are brought in during the winter, the same thing is observed to take place. No eggs or oviposition have been observed in the fields in the fall.

FIG. 6.—The clover-root curculio: Pupa. Greatly enlarged. (From Wildermuth.)

According to Wildermuth:

* * * the female deposits a large number of whitish eggs promiscuously on the leaves and ground or even on the side ofthe cage when confined. In the field eggs were found adhering to the lower leaves of both red clover and alfalfa. Within less than a day these eggs change in color to a shining black. It is very probable, however, that in the natural state the eggs are usually deposited at or near the surface of the ground. The egg period is 13 days in duration. The larvæ immediately after hatching go down into the ground. Great trouble was experienced in getting eggs to hatch in rearing cages, and it seems from this that there may possibly be some other as yet unknown condition entering into egg deposition in the field.

The adult beetle endeavors to escape injury or capture by feigning death. If a clover plant upon which this beetle is resting be touched the beetle drops to the ground and lies there an inactive and almost invisible object. It is only when in motion that one is able to see it readily, since its color harmonizes so well with its surroundings.

The larval period varies from 17 to 21 days, the latter being apparently nearer the normal.

The pupal stage is passed in an earthen cell, which is oval in outline, about three-sixteenths of an inch (5 mm.) long, and half as large in diameter. The time required for the pupal stage is from 8 to 10 days, easily determined independently of the other two stages by collecting mature larvæ in the field and rearing them to adults.

The larval period was determined by getting the combined length of the egg, larval, and pupal periods and subtracting from these the number of days required for the egg and pupal stages. This method was followed because of the difficulty experienced in getting the newly hatched larvæ to live after being transferred from the vial in which the eggs were hatched to a clover plant on which they could feed, and also because of the fact that the more fully developed larvæ, when disturbed to any extent, nearly always died. Thus, to avoid this, a record was kept of the day of the egg deposition in a certain cage, and then the beetles were removed and the cage left undisturbed but watched carefully until adults appeared. The time required for this was from 38 to 43 days, thus making from 17 to 21 days for the larval stage.

It will therefore be seen that there is but one generation of this beetle annually in the North, but the fact that adults readily deposit eggs at any time after October or early November if placed in a warm room would indicate that there might be more than one generation in the warmer portions of the country, although of course this does not necessarily follow.

FEEDING HABITS.

The feeding habits are, so far as can be determined, almost exactly the same on alfalfa as upon clover. So far as the beetles are concerned the amount of food consumed is almost a negligible quantity, and it is only where they gather upon clover plants along roadsides that this sort of injury becomes conspicuous. In confinement Mr. Parker found that the beetles preferred alfalfa leaves to those of red clover, eating them more readily. So far as it has been possible to determine, the larvæ have precisely the same feeding habits on alfalfa that they have upon clover. Therefore the statements of Mr. Wildermuth which follow are as applicable to the one plant as to the other, and they are quoted herein in full.

The larvæ of this beetle feed on the roots of all the plants mentioned as food plants. The smaller, more tender, or fibrous roots are eaten by the younger larvæ which, as they become more mature, attack the larger roots. Large cavities are eaten along the main roots, and often these are in the form of a groove containing the feeding larva [fig. 3, *a*]. An examination of clover roots, made on September 23, showed clearly the after effects of the work of the larvæ. The roots were eaten at various places, some of them appearing as though the whole surface had been eaten off, the roots being scabby and brown, the damage having evidently been done during late spring or early in the summer.

The adults feed on the leaves, eating out irregular patches from the margin of the leaf [fig. 3, *b*]. They are not as hearty eaters as some of the allied species of beetles that live on clover, and hence their work is not so noticeable, except when the beetles have developed in excessively large numbers, as was the case at Corning, N. Y.

FOOD PLANTS.

The following paragraphs relating to the food plants of the clover-root curculio are quoted, in substance, from Mr. Wildermuth:

While the clovers seem to provide the natural food plants of this insect, there are reasons for believing that others may in future be added. This insect, when first observed in this country by Dr. LeConte, was reported by him as present around the roots of grasses growing on sand dunes. Stephens, in 1831, reported it in England as being abundant on sandy heaths, which were no doubt grown up with grass.

The writer, in the spring of 1908, found the larvæ in large numbers in a blue-grass pasture. These were, to all appearances, feeding partly on blue-grass roots, as the only clover present was the white, and this was rather scattering in the field. From this it would seem that some of the grasses may be host plants.

Of the clovers, red clover appears to be the most common choice as a food, while white clover, crimson clover, and alsike clover are all fed upon to a greater or less extent by both the adults and larvæ. Alfalfa seems to be a common food plant for both larvæ and adults. On June 17 the writer collected numerous larvæ from among alfalfa roots in a field at Somerset Heights, Md., and while sweeping over a field of alfalfa with an insect net at Muirkirk, Md., on April 28, experienced no difficulty whatever in securing from six to eight adults with each sweep of the net. It seems likely that, with the increasing acreage of alfalfa, this insect may become a destructive pest and also menace this crop. The fact that alfalfa is always grown continuously on the same land for a fairly long period, from three to six years, or even longer, may greatly accelerate the rapidity with which the insect will be able to increase in numbers.

RECENT DEPREDATIONS IN ALFALFA FIELDS.

Now it will be noted that at the time Mr. Wildermuth's paper was prepared the insect had not been observed as seriously affecting alfalfa. The first absolute proof that we were able to secure in this direction was on May 29, 1914, when Mr. J. L. Graybill, county demonstrator, of Phoenix, Md., brought to the bureau office specimens of the beetle, and also alfalfa plants that had been irretrievably damaged by some insect, either identical with the larvæ of this species or some other one working precisely like them. Mr. A. B. Gahan was at once dispatched to the infested fields and took up the investigation of the difficulty on June 4. On visiting an infested field it was

found that the hay crop had been cut the previous day and was lying on the ground. There appeared to be a good yield on some parts of the field, but there were many places where the alfalfa plants were very thin and evidently decidedly unhealthy. Upon examining the roots of the alfalfa on these injured areas the main taproots, and often the larger lateral roots, were badly injured. In some cases the injury consisted of a groove, generally of considerable length, up and down the root, but often of a round or oval patch. The injuries appeared to extend to a depth of 4 or 5 inches below the surface of the ground. In one case the taproot of the plant appeared to have been eaten entirely off several inches below the surface of the ground. On digging into the soil, the first shovelful of earth turned up revealed between 12 and 20 larvæ of this insect about the injured roots, and further investigation revealed their presence even more plentifully in other areas of the field. This condition was reported by Mr. Graybill as occurring throughout all parts of Baltimore County, Md.

At the time of this investigation the larvæ (fig. 5) and the pupæ (fig. 6) were present in about equal numbers. That is, the ravages of the pest were subsiding. In all cases both of these stages were within an inch, or at the most an inch and a half, of the surface of the ground. Later on—on July 6—complaints were received, with specimens, from Mr. George A. Billings, of West Chester, Pa. Here again considerable damage had been inflicted upon alfalfa. On consulting with agronomists we have found that either this or a very similar injury to alfalfa has been observed for several years, but no one heretofore appears to have traced this injury to its source.

Mr. C. N. Ainslie found the beetles excessively abundant in alfalfa fields in April, 1910, about Salt Lake City, Utah, but of course at that time the larvæ were not at work upon the roots of the plants, and while during later years other assistants in cereal and forage insect investigations found the adults abundantly in alfalfa fields at various points in Utah, none of them succeeded in securing the larvæ or observing their ravages on the roots. The work of the insect is so obscure that it is likely to escape completely the attention of alfalfa growers.

NATURAL CHECKS.

Our information relative to natural checks, as also that to bird enemies, has not changed materially since the publication of Mr. Wildermuth's paper, and therefore the statements made by him are quoted.

> The larva was found to be attacked by a fungus, one of the Entomophthoræ, which no doubt assists in keeping the insects in check. The larvæ, because of their sluggish movements, might be easily captured and fed upon by predaceous beetles, but the fact that the larvæ and pupæ are subterranean in their habits is a semiprotection from parasitic insects as well as from many predaceous enemies. No Hymenopterous or Dipterous parasites were observed.

BIRD ENEMIES.

The Biological Survey, in its work on the food habits of birds, has found that the following birds feed upon the adults of this beetle: Upland plover, killdeer or killdee, ruffed grouse, broad-winged hawk, flicker, nighthawk, chimney swift, wood pewee, crow blackbird, meadowlark, Lincoln finch, song sparrow, chipping sparrow, and the white-throated sparrow.

Of these birds the chimney swift and song sparrow were found to be the greatest feeders on the insect, as many as 15 adult beetles being found in the stomach of one chimney swift, while but few less were found in stomachs of song sparrows.

REMEDIAL AND PREVENTIVE MEASURES.

Too short a period has elapsed since we have learned of the present and probably growing importance of this insect in the alfalfa fields to enable us to carry out extensive investigations of remedial and preventive measures.

This insect occurs generally throughout Europe and eastern Siberia as well as in England. It is known to be destructive in Europe to clover, but we have no records of serious damage to alfalfa outside of the eastern United States. Within the last year it has shown itself to be capable of working very serious damage in alfalfa fields and probably has been doing so for years, but on account of the obscure way in which the injury has been done its depredations appear to have escaped attention, although the effects upon the plants seem to have been noticed for a considerable time. If this condition can continue unobserved here in the East, there is no reason why it should not work serious ravages in the alfalfa fields throughout the entire United States where this crop is grown, and the cause of these ravages remain unnoticed even by experts. Now that we understand the nature and cause of these damages to alfalfa, it will be far easier to detect the work of the pest than has been heretofore the case. This bulletin is prepared for the especial purpose of calling the attention of alfalfa growers, county demonstrators, or other agricultural experts to its existence in this country, with the hope that the information will enable them to detect the pest in alfalfa fields and report its presence wherever found and in this way aid in anticipating and preventing as far as possible, by the most practical methods applicable under existing farm conditions, losses that might otherwise occur to alfalfa growers on account of the depredations of the insect in their fields.

Undoubtedly a short rotation of the alfalfa crop will have a tendency to limit the abundance of the pest in the fields. Of course this will not in any way affect the continuous breeding of the insect in waste lands or where clover or alfalfa occur uninterruptedly.

The limited amount of food consumed by the adults would of itself place the application of poisons out of practical consideration.

While the burning over of fields in winter when the ground is frozen might destroy some of the hibernating adults, in many cases they would probably be so near the soil, or so intermingled with the surface soil, as to escape the effects of the burning, and especially would this be true if they were further protected by a covering of matted green grass.

Therefore, at the present time the only practical suggestion that can be made is the disking or harrowing of the fields as soon as the first hay crop is removed. We know that the larvæ as a rule do not descend much more than an inch below the surface. If, therefore, the surface of the ground were disked and then harrowed, it would seem as though the pupal cells would be broken up, and as the pest is helpless in this stage, vast numbers would be destroyed in this way. While, as stated, there has not been sufficient time to carry out any exact experiments in this direction, it would be well for the farmers, until some better methods have been devised, to take the precaution of disking and harrowing immediately after removing the first hay crop in order to destroy as many as possible of the insects in their development. This, of course, can not be done early enough in the season to prevent injury, but it will in all probability reduce largely the abundance of the pest the following season.

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